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INVESTIGATING THE USE OF LARGE-SCALE IMMERSIVE COMPUTING ENVIRONMENTS IN COLLABORATIVE DESIGN

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ABSTRACT

Successful collaborative design requires in-depth communication between experts from different disciplines. Many design decisions are made based on a shared mental model and understanding of key features and functions before the first prototype is built. Large-Scale Immersive Computing Environments (LSICEs) provide the opportunity for teams of experts to view and interact with 3D CAD models using natural human motions to explore potential design configurations. This paper presents the results of a class exercise where student design teams used an LSICE to examine their design ideas and make decisions during the design process. The goal of this research is to gain an understanding of (1) whether the decisions made by the students are improved by full-scale visualizations of their designs in LSICEs, (2) how the use of LSICEs affect the communication of students with collaborators and clients, and (3) how the interaction methods provided in LSICEs affect the design process. The results of this research indicate that the use of LSICEs improves communication among design team members.

1. INTRODUCTION

As design challenges become more complex, interdisciplinary design teams become the norm. One of the biggest challenges in working in these teams is communication. Disciplinary experts use specific tools and vocabulary to communicate ideas among themselves. As each team member understands various aspects of the design within their own knowledge domain, design decisions are being made which cross domains. To avoid unnecessary redesign during development, in-depth understanding of interdisciplinary expertise by all team members is essential to effective decision making.

Modern immersive visualization tools are now available to educational institutions to assist in student learning. One specific example, the Large-Scale Immersive Computig Environment (LSICE), consists of large projection screen systems that display computer-generated product models at life-size scale. These environments can consist of a single wall or multiple walls (Fig. 1) and include a variety of interaction devices including wands, game controllers, haptic devices and gloves. The immersive nature of these environments means that they also include stereoscopic viewing and position tracking for at least one user. Some current LSICEs include the C6, Immersia 3, CAVE2, AlloSphere, StarCAVE, Reality Deck, and EVE[1- 7], among others. In this study, we evaluate the use of LSICEs by student design teams in an effort to show the impact that these tools can have in design education.

2. MOTIVATION

Visual representations of designs play a key role in many parts of the design process. Immersive computing environments offer the designer the unique opportunity to visualize and interact with each and every feature of their design in 3D space. One benefit of LSICEs is that they provide the user with the ability to see a model on a one- to-one scale, thus providing the opportunity to make more informed decisions about size and space. Evaluating size and space of potential designs is difficult when viewing models on a traditional computer monitor. For instance, envisioning how an additional 100 square feet will affect the ambiance of a room is challenging when evaluating the design as it is displayed on a screen that is only 22 inches across.

In product design, much like many other fields, decisions are made based on the entire life-cycle of the product, from the early stages of the product's life, such as how it will be manufactured and assembled [9], to the later stages, such as how the product will be used by the consumer. John Deere and

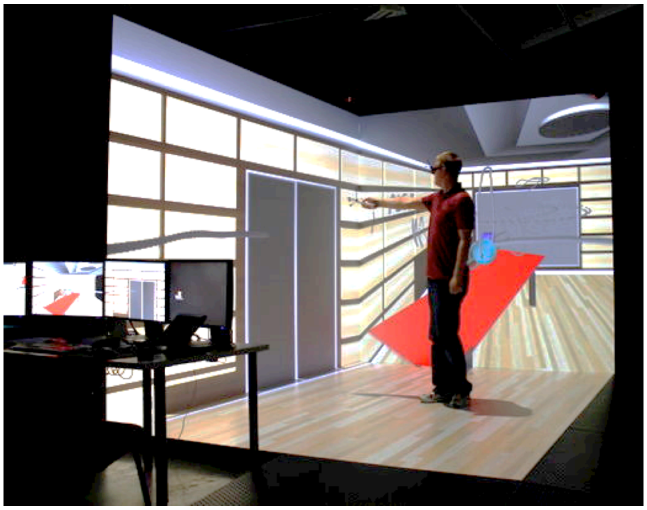

Figure 1. MULTIMODAL EXPERIMENTAL TESTBED AND LABORATORY (METAL)

Ford rely heavily on Immersive Computing Technologies (ICT) to ensure that the customer experience is ideally suited to a broad audience [10]. John Deere even uses this technology to train customers to use their products safely and effectively [11]. Many government agencies also use ICT when designing new products for manufacture. The US Navy used a six-sided LSICE during development of a new aircraft design in order to ensure that the planes would be compatible with current aircraft carriers [12]. Still others use ICT to evaluate the final stages of a product's life, such as how it will be dissembled for recycling of valuable materials [13].

Several researchers are studying how LSICEs can be used to facilitate collaboration between multidisciplinary designers that are separated by the boundaries of space and time [14]. Studies such as the one completed by Montoya et al. [15] highlight the importance of interacting with 3D models; however, in the environment in which they propose, users are not able to view the objects stereoscopically, potentially limiting users' abilities to fully explore the 3D geometry. Additionally, these studies do not address circumstances in which users are co-located.

3 RESEARCH QUESTIONS

Design education has become a testbed for multidisciplinary collaboration. Instilling this mindset in students early in their design careers has the potential to unlock numerous benefits. For this reason, the classroom was the ideal location to test the use of LSICEs in collaborative design. The research was motivated by three main research questions:

- Does the ability to visualize designs at a full-scale level using LSICEs improve the ability of designers to make decisions?
- How does the use of LSICEs affect the ability of designers to communicate with their collaborators and clients?
- How do the interaction methods provided in a LSICE affect the design process?

The results of this research will provide increased understanding of how design students in particular benefit from this technology and direction for future technology improvements to improve students' experiences.

4 METHODS

4.1 Participants

Thirty students enrolled in a third year design class at a large, midwestern university participated in this study. While the majority of the students were studying design and architecture, engineering and communications students were also represented in this class. In total, the class was composed of 15 design students, 13 architecture students, 1 communications student and 1 mechanical engineering student. Two of the design students had environmental studies as a second major. The participants ranged in age from 19 to 37 with an average age of 21.5. Students were in their sophomore, junior and senior years of study. Of the thirty students that participated, 21 were men and 9 were women.

4.2 Software and Hardware

For this study, students used the Multi-Modal Experimental Testbed and Laboratory (METaL) to visualize their models (Fig. 1). This system consists of three Digital Projection International TiTAN WUXGA-3D projectors projecting onto a single screen. An ART Track Pack 4 infrared optical tracking system provides head tracking and wand location for users within the system. Siemen's Teamcenter Visualization Mockup 9.1 was used to render the student's models in the immersive environment. A Bluetooth-enabled Logitech game pad with an ART tracker was used for navigation and interaction.

4.3 Procedure

The purpose of the course was for students to learn about the use of inter-operable digital design tools such as 3D modeling using computer-aided design software for use with human-scale interactive visualization technology. The students were given three projects throughout the course of the semester. Students were divided into eight small groups. Bi-weekly, each group used the METaL virtual environment to visualize their designs. During this time the students were given the ability to navigate around the virtual environment using the Logitech game pad. After viewing their models, they were given a week to iterate and improve on their designs. At the conclusion of the semester, the students presented their final projects to the instructor using METaL. After presenting their final projects, the students were asked to complete a survey regarding their experiences in the virtual environment. The survey consisted of three questions regarding the affect of the LSICE on communication, creativity and ideation ability as well as a short answer section about the perceived benefits and drawbacks of the virtual environment.

5 RESULTS AND DISCUSSION

The survey consisted of three questions asking them to rate the following on a 7-point Likert Scale:

- How much they felt that the environment hindered or improved their ideation
- How much they felt the environment hindered or improved their creativity
- How much they felt the environment hindered or improved their communication

On average, the students rated the LSICE as a 5.73 in terms of its ability to improve ideation (Scale: 1: hindered; 7: improved). With respect to the ability of the environment to support creativity, the students rated the experience an average of 5.69. The ability of the environment to support communication received the highest rating at 6.31.

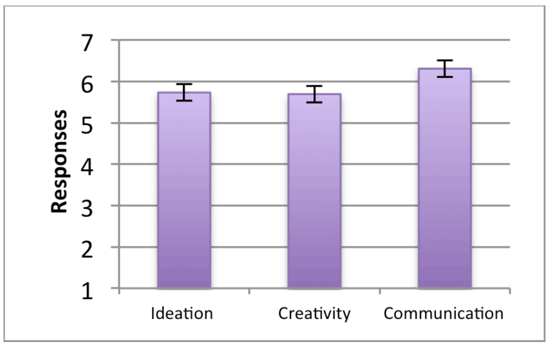

Figure 2. SURVEY RESPONSES

In addition, the students were also asked to provide written responses to these two questions:

- What was your favorite aspect about being about to use METaL to visualize your designs?
- What would you improve about the system if you could?

The students' responses to these questions provide some interesting insights into the research questions posed. Many of the students made comments regarding the opportunities provided in METaL to allow them to view their designs full scale.

> "It was very helpful to be able to view the projects at full-scale. By viewing them at full-scale, you could determine if elements of the design were sized correctly or if they needed to be altered."

Other students noticed the benefits of full-scale visualization over the use of computer monitors when creating a large design composed of many different components.

> "The life-size rendering. It gives you a more accurate feel than you would through the screen on a computer. It helped make alterations because sometimes what you thought was a good size for a component was in reality too big or vice versa. Sometimes you tend to lose track of scale in relation to your object and this helps a lot."

Additionally, students highlighted benefits of viewing their full-scale models in METaL as it relates to their abilities to communicate with fellow designers and clients with comments such as

> "Being able to use this technology is an advantage to designers in that they can see their designs in a real scale. This can be especially important with communication between designers and clients, as well as other contributors."

And

> "My favorite aspect is how it is bridging the gap from design intent to representation and communication. One large issue I see brought up again and again in design is the limited ways to communicate the intention and design to the viewer. The METaL lab is allowing a representation style unlike anything before."

Overall the majority of the students recognize the benefits of being able to see their designs in full-scale prior to creating prototypes.

LSICEs are also promising tools for creating more intuitive interactions with 3D models. Newer generations of students can hardly remember the days before keyboards existed. As such, we have learned to adapt our methods of interaction to accommodate these devices. For composing a word document or browsing the Internet, traditional input methods work just fine. They are not, however, intuitive to use for exploring 3D geometry. When a user interacts with a physical object, they use their hands to pick it up and examine it, rather than using a manipulation device analogous to the mouse. The lack of intuitive interaction with 3D objects using traditional interfaces makes viewing these objects in their full capacities quite challenging for non-experts. This is reflected in the following comment:

> "It is a whole new experience to be able to just look around a certain object rather than rotating it on the screen. I think because it is more intuitive to human nature, this system and others like it will be very successful in the future."

The students also had many insightful comments related to improvements that could be made to the system. Many of these suggestions centered around more accessibility to the system.

> "There needs to be more hands on training prior to using METaL and more training on using METaL itself. While the software is amazing and immersive, I haven't clue on how it works and I am muddling around in current design software as well."

One of the challenges associated with this technology is the steep learning curve associate with using it. Currently this limits the ability of the students to interact with the software one on one. Other improvements suggested by the students include improvements in the immersion provided by the system.

> "Close in the screens so it feels more immersive. Having the back open takes away from the feel of immersion."

These comments narrow in on the inherent flaws of virtual reality technology. While improvements in technology have made LSICEs much more accessible, there are still some challenges that need to be overcome.

6 CONCLUSIONS AND FUTURE WORK

Student responses indicated that the LSICE served as an aide in early design ideation, creativity and communication throughout the design project. Student comments supported the use of the LSICE for improved understanding of size and space and communication among team members. They also commented on the easy, natural interactions that supported transparent investigation of their designs.

Based on these results, we see many promising uses of LSICEs in design education. By educating the newest generation of engineers and designers in interdisciplinary design teams, supported with virtual reality tools such as LSICEs, students will develop an understanding of how to use these technologies to make decisions during the design process. They will look to virtual reality tools to support their ability to collaborate, blurring the lines that separate various disciplines by interacting with life-size virtual models using natural human motions in the design decision-making process. As technology advances, these tools have the potential to become as commonplace as the monitor, keyboard and mouse; effectively changing how we interact with early stage design concepts.

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